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THE PREDICTION OF LUNG CANCER RISK FROM EXPOSURE TO RADON PROGENY BY MICRODOSIMETRIC MODELS

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Introduction

In the last period an important motivation for the study of the radon in the outdoor atmosphere is using of the ^{222}Rn and its decay products in the atmospheric studies, especially for the determination of the atmospheric stability. The new knowledge about behaviour of the radon and radon daughters in the atmosphere are needed also for more precise determination of public radiation exposures from radon.

In this contribution the influence of the meteorological conditions on activity concentrations of the outdoor ^{222}Rn and its daughter products is discussed in detail. In addition, the correlation between concentrations of measured radionuclides is studied and empirical relations for concentrations of radon daughter products are presented.

Model

The geometric model used for the calculation of Lung Cancer Risk is displayed in Figure 1. Bronchial airways are approximated by cylinder tube of diameter 4400 µm (4. generation). The alpha activity concentrations of ^{214}Po and ^{218}Po in the different bronchial airways were computed for exposure conditions typical for underground miners as given by the ICRP Publication 66 Human Respiratory Track Model (HRTM) [2]. ^{214}Po and ^{218}Po alpha particles were emitted isotropically from the mucus/"sol" layer, with exponentially decreasing source distribution (half-value layer 6 µm). The thickness of the mucus source shell was 11µm for a non-smoker and 30 µm for smokers (Figure 2).

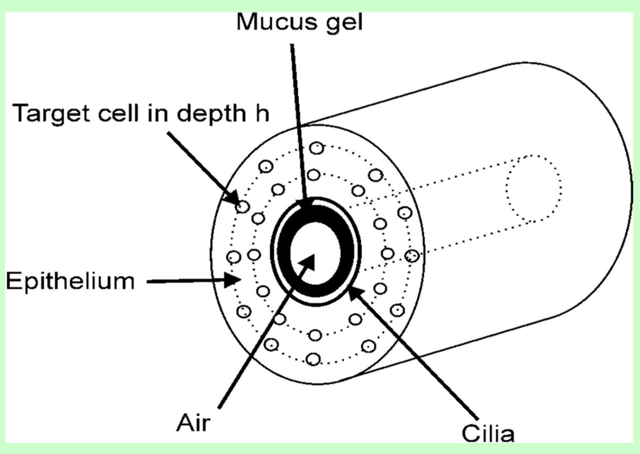

Fig.1 Geometric model.

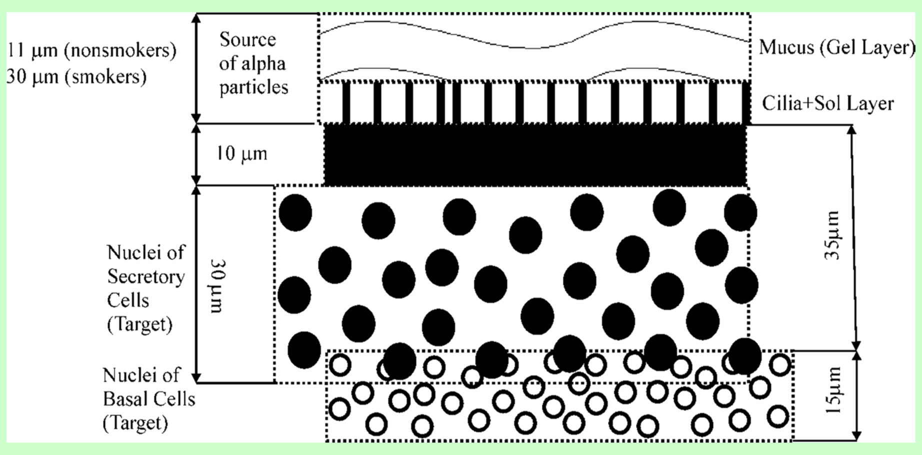

Fig.2 Model of target cell nuclei.

Energy deposition in the tissue and in the air gap was calculated by the Bethe-Bloch equation. The target nuclei of bronchial epithelium were represented by spheres of 5 µm diameter and were placed in the lung tissue in 5 µm steps along radii of the cylinder. We assumed that the inactivation of cells at a dose D would occur after exceeding a threshold value of specific energy z_0 in the target [3]. The lower value of z (compared to z_0) may lead to cell transformation. In our study we used the specific energy for inactivation $z_0 = 0.9$ Gy. The use of other z_0 values have no influence on the shape of the transformation function T(D).

Results and discussion

For the given thickness of the mucus the radiation response $R_{mucus}(Ex)$ (for different cumulative exposures *Ex* of lung) was obtained by summation of respective probabilities of biological responses over all depths (in 5 µm steps) in airway generation:

$$R_{mucus}(Ex) = \sum_{i \in \left\{ \begin{matrix} 10\mu m, 15\mu m, 20\mu m, \\ 25\mu m, 30\mu m, 35\mu m, \\ 40\mu m, 45\mu m, 50\mu m \end{matrix} \right\}} \left\{ p(i) \left[\int_0^{\infty} \left(S_{i,mucus} * T_{i,mucus} \right) f_{i,mucus}(\Omega) d\Omega \right] \right\}$$

where $f_{i,mucus}(\Omega) d\Omega$ is the fraction of cells at the given depth *i*, for which the probabilities of cell transformation $S_{i,mucus} * T_{i,mucus}$ falls within $S_{i,mucus} * T_{i,mucus} \in (\Omega, \Omega + d\Omega)$

In our calculations the heterogeneous depth distributions p(i) [4] of target nuclei were considered.

The thickness of the mucus shell was influenced by smoking habit (11µm for non-smokers and 30 µm for smokers). We inserted the mean cycle time τ of bronchial cells into the model. The biological response for miners Y_{mine} has been calculated as follows:

$$Y_{mine}(Ex) = q_{nonsmoker} * R_{11\mu m}\left(Ex * \frac{\tau}{\tau_{exposure} * 365}\right)$$
$$+ (1 - q_{nonsmoker}) * R_{30\mu m}\left(Ex * \frac{\tau}{\tau_{exposure} * 365}\right)$$

and relative risk is expressed as:

$$RR(Ex) = 1 + \beta * Y_{mine}(Ex)$$

where $R_{11\mu m}$ ($R_{30\mu m}$) are the weighted biological endpoints for the thickness of the mucus source 11µm (30µm); *Ex* cumulated exposure, $\tau_{exposure}$ is time of exposure, $q_{nonsmoker}$ is fraction of nonsmokers. β is the calibration factor. The parameter values of β were obtained by fitting equation (3) on the epidemiological Lubin´s data [5] using the weighted least squares method (reciprocal value of the square of deviation was used as a weight).

From the calibration curve we have estimated the ERR for smokers and nonsmokers working in the underground surrounding. The results are summarised in the Tab.1. and compared with the epidemiological data [5] given in the Fig.3.

The indoor radon exposure with a radon concentration of 231 Bqm^{-3}, represents equal biological risk as a cumulative exposure of 25 WLM underground. By applying this philosophy and using our calibration curve we have calculated ERR for dwellings, supposing that approximately 35 % of the whole population are regular smokers. The results are given in the Tab.1. and are compared with epidemiological data in dwellings (see Fig.4).

The value of excess relative risk from epidemiological data represents ERR = 1.5 (95%CI = 0.0,3.0) [8]. The ERR value of 1.5 (95%CI = 0.0,3.0) 10^{-3} Bq^{-1} m^3 is in good agreement with our value ERR=1.1 (95%CI = 0.9,1.2) Bq^{-1} m^3.

Tab.1 Excess Relative Lung Risk (ERR), and 95% CI for miners and residential.

Type smoking	MINE	HOME
	ERR [WLM^{-1}]	ERR [Bq^{-1} m^3]
ALL	4.0 (3.5,4.5)	1.1 (0.9,1.2)
Smoker	3.2 (2.8,3.5)	1.4 (1.2,1.6)
Nonsmoker	7.5 (6.6,8.4)	0.4 (0.4,0.5)

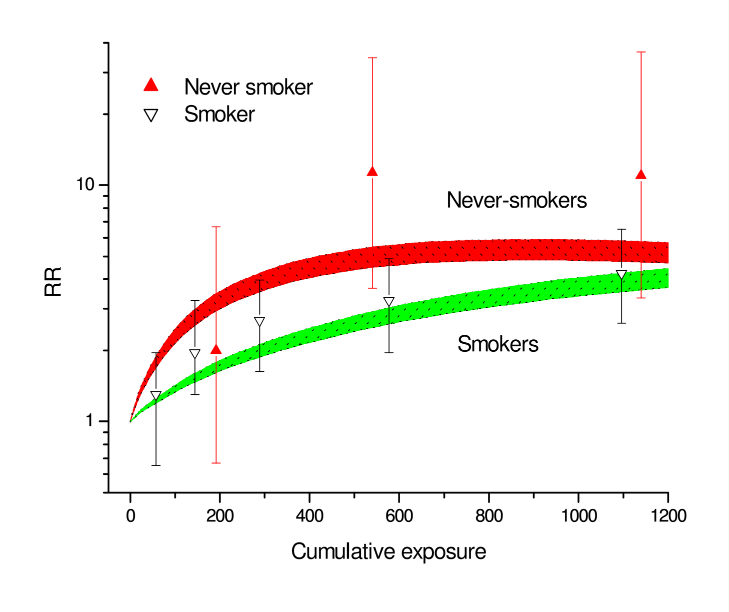

Fig.3 RRs of lung cancer for never-smokers and smokers in miners.

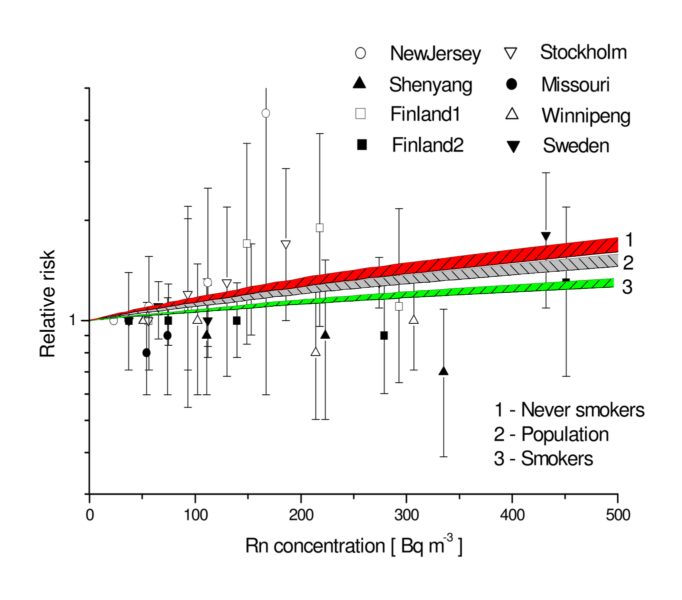

Fig.4 RRs of lung cancer for never-smokers and smokers in dwellings.

Conclusion

- For the prediction of cancer risk following the exposure, it is also necessary to consider the mean cycle time of target cells. From our analyses it can be concluded that the mean cycle time of target cells should exceed 100 days.
- The value of excess relative risk is for smokers ERR= 3.2 (95%CI = 2.8,3.5) WLM^{-1} and that of the nonsmokers ERR=7.5 (95%CI = 6.6,8.4)WLM^{-1}, considering the underground medium. Excess relative risk for the smokers ERR= 1.4 (95%CI = 1.2,1.6) Bq^{-1} m^3 and for nonsmokers ERR=0.4 (95%CI = 0.4,0.5) Bq^{-1} m^3 is supposed in dwellings

Microdosimetric models are very helpful and suitable for prediction of the radon risk for underground conditions, as well as for indoor radon risk evaluation and they are also able to take into account the influence of the smoking habit.